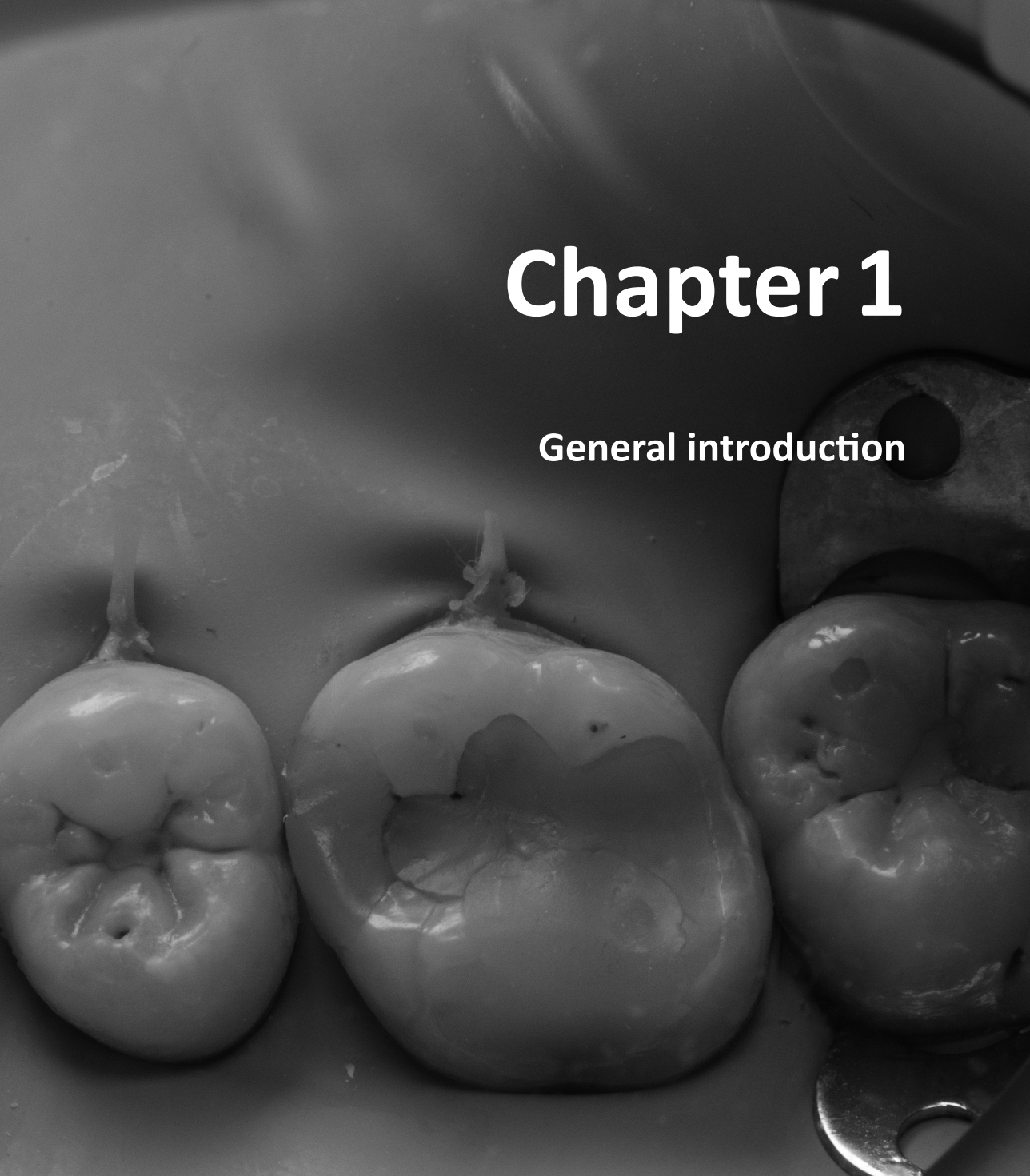
# Chapter 1

## General introduction



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# General introduction

## Restoring dental tissues: indirect versus direct

Dental hard tissues, missing due to caries or trauma, can be restored using various dental materials in an attempt to re-establish the lost biomechanical, functional and optical features of the tooth. In restorative dentistry, restorations are made using either indirect or direct fabrication methods. Direct restorations by means of resin-based composite materials are associated with a less time consuming clinical workflow, namely tooth preparation is followed by providing the restoration in the mouth in one clinical session. On the other hand, indirect restorations require a workflow of tooth preparation, impression making, temporary reconstruction, laboratory fabrication and finally the permanent delivery of the restoration. Such restorations were traditionally made using either gold or metal-ceramic. Recent advances in glassy matrix and polycrystalline oxide ceramics, as well as in polymeric materials allow for the elimination of metals used as a base for the restoration and because of superior light dynamics better optical results can be offered. Depending on the amount of tissue loss and the aimed optical outcome, both direct and indirect restoration methods can be indicated.

## Consequences of full circumferential versus partial tooth preparation

Unfortunately, the indirect restoration methods require more reduction of tooth material in order to achieve optimal thickness for mechanical durability of the restoration material as opposed to the direct method.[1] Dentists often use tooth preparation for full crowns and fixed dental prosthesis (FDP) by full circumferential removal of intact enamel and/or dentin (Fig. 1a-1b), which serves for macro-mechanical retention of the restoration.[1] This yields to several biological consequences such as tooth sensitivity. Furthermore, particularly in deep preparations close to the pulp, loss of tooth vitality occures, needing root-canal treatment.[2,3] Clinical studies show that 0.8-5.6% of single all-ceramic crowns and 2.8-5.9% of all-ceramic FDP's suffer from endodontic complications within 5 years post-operatively.[4,5]

With the advances in adhesive technologies, restorative materials can be bonded to dental tissues where their survival does not rely on mechanical retention principles alone, but also on physicochemical interactions between the enamel/dentin-luting agent-restoration complex. Consequently, the conventional tooth preparation concepts for indirect restorations have changed over the years: partial tooth preparation became adequate for restoring the missing dental tissues (Fig. 1c) when using restorative materials that can be adhered to. The preparation design according to this method is less time consuming and mainly involves removing the caries, old restoration material and undercuts followed by smoothening of the tooth surface.


**Figure 1a-c**. Images of a) intact tooth (white = enamel, yellow = dentin), b) full circumferential tooth preparation that requires removal of a substantial amount of enamel and dentin. Note the complete removal of enamel. c) partial tooth preparation that requires less removal of sound tooth structure. Note the presence of enamel.

While full circumferential tooth preparations can result up to 67.5% to 75.6% of tissue loss, partial tooth preparation yields to 5.5% to 27.2% of tissue loss, hence can be considered substantially less invasive.[1] Teeth prepared employing a partial tooth preparation method can be restored with either an inlay, overlay, onlay or veneer. The clinical survival of such minimal restorations in the posterior region ranges between 92% and 95% after 5 years,[6] and 91% after ten years,[6] depending on the material type. The most frequently reported complications are fracture/ chipping (4%), endodontic complications (3%), secondary caries (1%) and debonding of the restoration (1%).[6]

## Advances in luting materials

The longevity of indirect restorations made of ceramic materials is highly dependent on the adhesive procedures that entails conditioning the tooth surface, conditioning of the intaglio surface of the restoration, the type of luting agent and the polymerization protocols.[7] Both glassy matrix and polycrystalline ceramics require physical-chemical surface conditioning methods in order to achieve micromechanical retention of the resin composite to such ceramics.[7] While glassy matrix ceramics are typically conditioned using hydrofluoric acid followed by cleaning and silanization and adhesive resin application,[8] the polycrystalline ceramics require initial surface roughening using air-borne particle abrasion, silanization and the use of phosphate monomer containing resin composite when adhesion to the restoration material is desired.[9,10] A large number of studies have dealt with this topic over the past decades with varying results, as a result of the chosen test method employed for assessing the adhesion potential of luting cements. Therefore, there exists perplexity as to which luting agent results in a durable adhesion for each ceramic material, which is essential for the longevity of indirect restorations.

It also has to be noted that adhesion has two components: both to the restorative material and to the dental tissues, namely enamel and/or dentin. Adhesion of resin-based materials to enamel is well-established using 35-38% phosphoric for the removal of hydroxyapatite from enamel prisms selectively, yielding excellent, durable, micromechanical retention. However, durability of adhesion to dentin is still considered challenging due to the nature of dentin.[11,12] Adhesion to dentin is more

difficult to accomplish and is less predictable as dentin is a porous material that contains a significant amount of water and organic material.[12] Dentin is composed of apatite crystal particles embedded in a proteinaceous matrix that includes type I collagen. It is intimately connected with pulpal tissues through numerous fluid-filled tubules.[13] Under constant outward pulpal pressure, this fluid flows to the exposed dentin surface that is naturally moist and thus intrinsically hydrophilic. [13] The hydrophilic dentin definitely presents a major challenge for the interaction of modern adhesives with this substrate. For this reason, many dental adhesives combine hydrophilic and hydrophobic monomers in their chemical composition.[14] While hydrophilic groups enhance the wettability to the dental hard tissues, hydrophobic groups interact and copolymerize with the restorative material. Consequently, the manufacturers have developed dentin adhesives that are compatible with humid environments. In this context, water plays another important role in the partial hydrolytical degradation of adhesive polymers, decreasing their physical properties over time. Furthermore, absorption of water at the dentin-resin interface leads to plasticization of the adhesive resulting in lower bond strengths.[14-17] This phenomenon could potentially be overcome by optimal sealing and infiltration of the dentin.

## Immediate Dentin Sealing (IDS)

In adhesion studies on dentin, the vast majority of the laboratory studies focused on freshly cut dentin but this can only represent the type of dentin encountered in direct restorations but not in indirect ones. In direct restorations, typically after etching or conditioning the dentin with acidic primers and application of adhesive resin, resin composite is directly bonded onto dentin. The adhesive resin infiltrates into the conditioned dentin, completely sealing the collagen, forming a hybrid layer. Immediate adhesive application after preparation for direct restorations results in optimal adhesive strength.[18] This procedure is a routine step when providing direct restorations.

In the workflow of indirect restorations, adhesive promoters are predominantly applied before luting the indirect restoration, referred to as “Delayed Dentin Sealing” (DDS). Thus, with the DDS method, a hybrid layer is created at the final stage of the luting workflow that is then subjected to immediate loading of the restoration (Fig. 2). However the results of this delayed application of the adhesive layer results in lower adhesive strength.[19,20] Therefore, the IDS (Immediate Dentin Sealing) method has been proposed to seal the dentin immediately after tooth preparation but prior to impression taking. [11] Applying an adhesive resin layer directly after tooth preparation in an indirect workflow (Fig. 2) was postulated to protect the pulp from bacterial invasion, avoid surface contamination during the temporary phase, protect dentin by hybridization, reduce post-operative sensitivity, prevent water-uptake and increase bond strength.[21]

The clinical problem related to hypersensitivity is in fact multifactorial.[22] Dentin exposure may cause bacterial diffusion and trigger a pulpal inflammatory response with subsequent formation of reparative dentin.[23-25] In several studies, a significant correlation between microbial microleakage and pulpal inflammation has been demonstrated.[24,26-28] In a relatively short period of time (up to 4 days), bacteria can infiltrate the tubules and the odontoblastic processes, collagen fibers, kinetics of tubular

fluid, and immunological function do not seem to be sufficient to inhibit this process.[22] Prevention of hypersensitivity in indirect restorations could be performed by the application of adhesive resins (IDS).[21] In addition, immediate application of the adhesive resin has the benefit of increased maturation before luting the indirect restoration as the tensile stress on the hybrid layer is postponed for several weeks.[19,29,30] In laboratory studies the benefit on adhesive strength of the IDS method in comparison to a delayed adhesive application was demonstrated.[19,30,31]

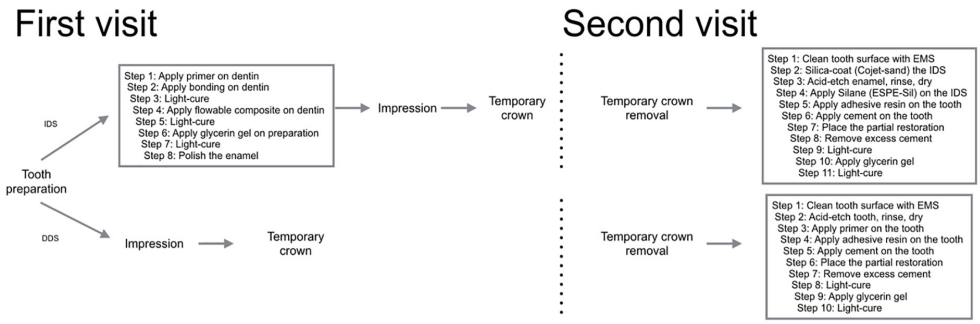


**Figure 2**. Different workflows of Immediate (IDS) and Delayed (DDS) Dentin Sealing procedures.

## Aspects of IDS

Although the application of IDS improves the adhesive strength in different *in vitro* studies the application method is still debated. Some studies used only one adhesive bonding system while others modified the system by the application of two or more adhesive layers or included the use of a flowable resin layer. Moreover, there is no consensus to date as to which method is most suitable for optimal conditioning of the IDS coated dentin prior to luting the indirect ceramic restoration. Several methods have been recommended to clean and condition the IDS surface, such as mechanical cleaning with pumice or air-borne particle abrasion using alumina or silica-coated alumina particles.[32] Furthermore, little is known on how the IDS or DDS influences the fracture strength and longevity of partial restorations. These questions form the backbone of this thesis.

## Objectives of this thesis

The following objectives were addressed in this thesis:

1- to organize the current knowledge and the manner in which cements are used for the cementation of glass-ceramics, with a particular emphasis on the benefits of IDS;
2- to evaluate the IDS application methods using different adhesive resin systems and surface conditioning methods and employing different adhesion test methods in vitro;
3- to assess whether the fracture strength of ceramic and composite materials are affected by the application of IDS;
4- to evaluate tooth sensitivity, patient satisfaction and clinical survival of partial posterior ceramic restorations bonded employing the IDS or DDS method in a randomized clinical trial;
5- to asses the clinical performance of ceramic partial restorations with the use of IDS prospectively.

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